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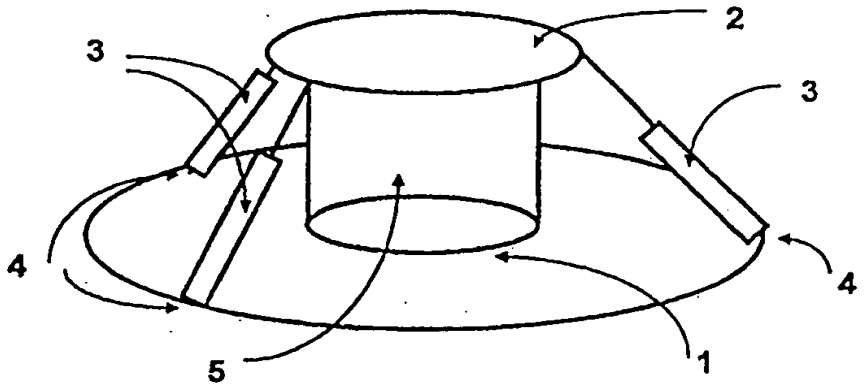

(57) Abstract

Apparatus for simulating motion in the form primarily of a seat having arrangements for providing the user with cues which influence the users perception of apparent motion, particularly sustained movements. A fixed seat frame has a moveable seat from which can tilt about orthogonal roll and pitch axes and be displaced linearly in the heave, surge and sway directions: all movements are small and are accompanied preferably by synchronised variations in the apparent hardness of regions of the contact surface so that a user experiences the small relative displacements and apparent tendency to slip in relation to the seat in synchronisation with other cues which result in an interpretation of the experience to simulate the effects of real motions without actually involving movement. This may reinforce the effects of a convention motion simulator, for example for flight training.

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IMPROVEMENTS IN SIMULATORS

The present invention relates generally to improved means for simulating at low cost the sensations of motion that would be experienced by a seated traveller in a vehicle, without creating such movements.

It is known to use the adjustment of fluid pressure in a plurality of flexible enclosures or pads in order to create a subjective sensation of motion in a flight simulator. In US-A-4059909 and in the Applicant's own co-pending application PCT /GB93/ 01788 the human body is supported on a support surface held up by air pressure. The area of the support surface may be carried on a series of pads in such a way that variation in the pad air pressure will vary the way the body contacts the surface, that in whether it detects the surface as hard or soft. The air pressures used in the pads are generally in the order of 0.1 bar, which makes the air support soft. A special material within the pad, which has a strong gradient of hardness with compression, provides the hardness varying in effect so that by changing the air pressure in the pads the degree to which the body is supported by the material may be altered and thus the apparent hardness of the supporting surface can be controlled. The term "hardness" of a material as used herein means the rate at which the opposing force increases as a body intrudes into its surface.

It is known that the brain interprets the apparent hardness of a surface with which the skin is in contact in part as a measure of the force which is being applied to the skin by that surface. Further, a human being quickly learns that force produces

acceleration and that the sensations of acceleration are preceded by certain clues such as an increase in the apparent hardness of a surface which is in contact with the person's body. It is therefore possible to produce false perceptions stimulating the sensations of motion by arranging to apply an appropriate pattern of hardness variations, synchronised with other stimulations such as visual and audible sensations. The illusion is the basis of the flight simulator "g seat" as previously developed, in particular by Kron and described in his US Patent referred to above.

Known such devices have several shortcomings. One important problem is that of latency - the time for an electronic signal to produce a real physical effect. Whilst the use of pistons driven by electromagnetic actuators produces a significant improvement, the thermodynamic properties of the intervening mass of gas prevent the action from being both rapid and precise.

Further, the operation of the seat induces a peculiar and to some extent unreal feeling. This is because, in the absence of real changes in acceleration, the transfer of body pressures to different areas of hardness has a side effect that causes the pad contact area to compensate automatically whenever the human occupant makes any unconscious movement. The result is that the seat areas themselves feel "alive".

A second cause of unreality is the absence of a "scrubbing" or "tug" to the clothing that accompanies a real lateral accelerating force applied to a body in contact with a supporting surface. In reality the body tends to roll or slide across the surface

with which it is in contact for example when experiencing a cornering force in a road while producing a noticeable transverse "tug" sensation associated with the clothing and the skin, which the brain learns to expect.

Kron therefore suggested that, in addition to the pressure-pad hardness modulators, the surfaces of the seat - especially the surface of the seat pan - should be designed to move slightly in the appropriate directions so as to seek to imitate the "scrubbing" cue.

There are, in addition, some practical difficulties associated with the use of air-inflated pressure pads in simulator seats. The pad surfaces are not well protected and so they are vulnerable to puncture, by accident or by intent. A seat of reasonable quality will require a large number of pads each with associated air-tight seals so that air leaks will be almost inevitable in due course. In an amusement location in which such simulation seats might be used this would mean a high maintenance overhead. In the home there is no central air supply that can be used for the machine and each simulator seat would have to be provided with its own compressor. However, if leaks was to develop (as they inevitably will) the compressor would have to operate for most of the time that the apparatus were in use, causing a distracting and unacceptable noise, and quickly wearing out.

Previous designs of simulator seat have applied hardness modulation by means of pressure pads, or have applied real seat motions directly, or have added pressure pad systems to gross movements of a seat such as on an aircraft training simulator.

The present invention seeks to provide a form of simulator that does not rely on pressure-pad hardness modulators (although such may be optionally provided) nor involve the gross physical movments of known simulators. In the present invention a simulator seat to which a (limited) seat motion is applied is provided with means by which additional cues which provide the user with perception of motion are generated without requiring actual motion to take place apart from very small cue motions.

According to one aspect of the present invention, there is provided apparatus for simulating motion comprising a support surface capable of at least limited rotary displacement about at least one axis, and optionally also translation in a direction transverse the said one axis, whereby to provide a simulated sensation of motion to a user supported by the support surface.

According to another aspect of the present invention there is provided a method of simulating motion by causing displacements of a support surface in relation to a user supported thereby in the directional sense of the relative motion which would take place between the user and the support surface as a consequence of the simulated motion.

It will be appreciated that such movements are often in an opposite sense from that of the simulated motion in that they are applied to cause the relative motions between user and surface that occurs as a result of that motion. For example, to create a perception of a turn to the left in a road while the support surface is tilted

down to the right so that the user will experience a slight tendency to slide to the right in relation to the seat, while in part of the subjective perception of a left turn.

In a preferred embodiment of the invention the support surface is further provided with means for varying its apparent hardness in synchronisation with displacement about or transverse the said one axis whereby to influence the perception of apparent motion on the part of a user supported on the said surface.

Preferably a first auxiliary support surface contactable by a part of a user supported on the said support surface and displaceable with respect to the said support surface at least in the said direction transverse the said one axis is provided. Likewise it is preferred that the said first auxiliary support surface is also displaceable with respect to the said support surface in at least one direction generally transverse to the said transverse direction.

Embodiments of the invention may also be envisaged in which there is at least one second auxiliary surface inclined to the said support surface and diplaceable therewith about the said at least one axis and/or in the said direction transverse the said one axis.

In a simulator seat such as second auxiliary surface may be, for example, a sides surface against which a user's hips may engage as the support surface is tilted and/or laterally shifted, to give the user a further clue to reinforce the perception of apparent movement.

There may also be a third auxiliary surface spaced from the said support surface and displaceable by translation in at least two directional senses of at least one direction in association with the displacement of the said support surface.

Additional cues to reinforce the perception of apparent movement may be provided if the said support surface, and/or the said first auxiliary surface and/or the second auxiliary surface has or have means for varying its apparent hardness. In embodiments having this feature it is preferred that the said means for varying the apparent hardness of the said support and/or auxiliary surfaces is operative to vary the apparent hardness of a limited region of the overall area of the said support surface and/or auxiliary surface.

In the present invention a motion base having at least three axes of freedom may be incorporated into the structure of a simulator seat so that the seat pan may be moved though a small distance and through small angles in relation to the fixed part of the seat, the movements of the seat pan being optionally arranged to induce simultaneous or phased variations in the apparent hardness of the seat surface for example by varying the extent to which hard protrusions extend into the body of the seat cushion, the seat pan optionally being also provided with other means for supporting the deadload of the seat occupant . It will be understood that the hardness variations produced in such a system should be in the correct sense to convince the occupant that the seat is moving against the inertia of the body of the occupant. The technique also produces the appropriate sensations of skin tension.

Various embodiments of the present invention will now be more particularly described, by way of example, with references to the accompanying drawings, in which:

Figure 1 illustrates a 3-axis motion base of the type which may be used in a construction embodying the present invention;

Figure 2 is a schematic cross sectional view of a known hardness modulation system;

Figure 3 is a cross sectional view of another hardness modulation system which can be used in embodiment of the present invention;

Figure 4 is a diagramatical view of a set of three linear actuators usable for creating the movement of a seat pan incorporated in an embodiment of the present invention;

Figure 5 is a cross section illustrating the major components of alternative embodiment of the invention;

Figure 6 is another cross sectional view showing an alternative support system;

Figure 7 is a schematic plan view of a support surface showing the location of some of the actuators usable theren; and

Figure 8 is a schematic side view of a seat formed as an embodiment of the present invention.

Referring now to the drawings, and particularly to Figure 1 thereof, there is shown a platform as described in our co-pending British Patent Application No. 9709737 the disclosure of which is incorporated herein by reference, comprising an upper platform 2 moveable about the pitch and roll axes in relation to a stationary

platform 1 by means of actuators 3, which may be electromagnetic actuators of the form described in one of our several co-pending applications such as PCT/GB9B/00495 or PCT/GB9B/03088. The central member 5 functions both as a support for the deadload and as a constraining element that prevents the upper platform from twisting or being laterally displaced Linear Motion parallel to the yaw axis (heave) may also be achieved.

In the present invention the underlying surface of the seat pan may be considered to be the upper platform 2 in a similar construction that is moved by small actuators 3 in relation to the stationary part of the seat 1

Figure 2 illustrates the general principles of a prior art pressure pad hardness modulator. The occupant of the seat has part of the body surface upon or bearing against the surface of a membrane filled with air at variable pressure (being varied in this illustration by means of the piston and chamber to which it is connected). The hardness is modulated by varying the relative proportion of the area of the skin that is in contact with the underlying hard surface. The seat occupant may be considered to be lifted from or lowered onto a hard surface by the action of the device.

Figure 3 illustrates the alternative method of hardness modulation that is adopted in certain embodiments of this invention. The upper diagram shows the system in its condition of softest support; in which the occupant is supported by or bears against a relatively thick cushioned surface 30 that transfers the force onto a hard underlying plate 32 forming the base of the seat pan. The seat pan plate 32 is the

moving element of a motion platform. The plate has in it a number of holes, through which pass hard protrusions 34 from a fixed underlying surface 35.

Suppose that the cushion-carrying plate 32 is lowered, as in the central diagram. It will be understood that the cushion becomes harder, because the effective area of the underlying support surface, now the top of the protrusions 34, has decreased and the cushion 30 is more compressed. The sensation is that the seat has pushed upwards into the cushion 30 - although the reverse is actually true.

Suppose now that the seat pan 30 is tilted through a small angle, as in the lowest diagram. It will be understood that the buttocks of the occupant will experience an increased hardness in the direction of the downward tilt and a decreased hardness on the opposite side. It will also be understood that the occupant will experience the correct rolling and skin shear sensations for such a motion and again it will produce the sensation that the seat is moving in the opposite direction.

Thus, by seat pan tilting alone, hardness modulation and lateral slip sensation can be simultaneously produced in the correct sense. No pressure pads are used. Even in embodiments which do not use hardness modulation, the slight tilting, which may be accompanied by a lateral shift or translational movement away from the direction of tilt, is sufficient to provide the psychological cue to the perceived motion being simulated by the apparatus.

Figure 4 shows a diagrammatic arrangement of the three actuators 41 to create the

3-

axis motion of the seat pan. The actuators form a triangle, two at the rear, in the region of the ischial probosces and one at the front of the seat pan. The seat pan is supported a small distance above the stationary part of the seat structure. It will be understood that the actuators 41 are not constrained to fit into this space but may conveniently extend downwards into cavities beneath the lower plate and be angled if necessary.

Figure 5 illustrates one of the ways in which the deadload of the seat occupant may be supported. It will be understood that if electromagnetic actuators 41 are used it is necessary to support the deadload by means other than electromagnetic forces in order to reduce the power consumed. The diagrams show a centrally-placed gas-filled bellows 51 as described in our co-pending application GB9709737.0. The bellows need not be circular and may follow the contour of the periphery of the moving plate. Alternatively, a mechanical spring or a set of proprietary high-pressure nitrogen gas struts may be employed. The large bellows 51 might be inflated by a small pump or the mechanical systems (not shown) adjusted by a manual screw tensioning arrangement so as to adapt the support to the weight of the occupant.

Figure 6 shows an alternative low-cost support arrangement in which the cavity separating the two surfaces is packed (between the raised hardness-modulating pillars and the actuators themselves) with resilient closed-cell plastic foam 61.

Figure 7 illustrates a plan view of the main area of the seat, showing the presence of side pads 55 on supports 56 (actually sloping inwards) that bear upon the outer

surfaces of the thighs of the occupant. It will be understood that when the seat pan is tilted to one side, the pressure on that thigh will be increased and the pressure on the other thigh will be decreased, as appropriate to the acceleration that is being simulated. Similarly, vertical movements of the seat pan will produce appropriate sensations on the thighs by a wedging action. The diagram also shows the backrest 56 with cushion 55 by which a portion of the weight of the occupant is supported. (See also figure 8) A number of small actuators (not shown) may be fitted to the backrest in more elaborate versions of the seat, so as to drive hardness modulators in areas of the back support cushion so as to simulate strong forward or braking accelerations.

Likewise, small movements of the backrest may also be produced by an appropriate coupling by levers in anti sense to the motions of the seat pan. For example, a forward tilt of the seat pan, simulating a braking action or negative surge, may be arranged to induce a small backward tilt of the seat back. Similarly a downward motion of the seat pan, simulating a strong upward surge, may be arranged to produce a small upward motion of the seat back, and so on,

Figure 8 shows a side view of the seat, demonstrating the small backward angle that is necessary to ensure. that the occupant sits firmly into place and that the feet are outstretched with the heels resting on a raised footrest unit 52 with cushion 51. A small actuator (not shown) may be used to transfer sensations of vehicle vibration to the feet via the footrest, so as to enhance the illusion of a moving seat.

It will be understood that, although it is not discussed in detail in this document,

the seat belt tensions are also modulated in the appropriate manner and in synchronism with the other motions of the seat.

Hardness modulations may also be simulated by displacing the protrusion 34 in relation to the seat 32 to vary the apparent hardness of the cushion 30 without requiring tilting of the seat pan.

CLAIMS

1. Apparatus for simulating motion comprising a support surface capable of at least limited rotary displacement about at least one axis and optionally also translation in a directon transverse the said one axis whereby to provide a simulated sensation of motion to a user supported by the support surface.

2. Apparatus according to Claim 1, in which the support surface is further provided with means for varying its apparent hardness in synchronisation with displacement about or transverse the said one axis whereby to affect the perception of apparent motion on the part of a user supported on the said surface.

3. Apparatus according to Claim 1 or Claim 2, further including a first auxiliary support surface contactable by a part of a user supported on the said support surface and displaceable with respect to the said support surface at least in the said direction transverse the said one axis.

4. Apparatus according to Claim 3, in which the said first auxiliary support surface is also displaceable with respect to the said support surface in at least one direction generally transverse to the said transverse direction.

5. Apparatus according to Claim 4, further including at least one second auxiliary surface inclined to the said support surface and displaceable therewith about the said at least one axis and/or in the said direction transverse the said one

axis.

6. Apparatus as claimed in Claim 5, further including a third auxiliary surface spaced from the said support surface and displaceable by translation in at least two directional senses of at least one direction in association with the displacement of the said support surface.

7. Apparatus as claimed in any preceding claim, wherein the rotary and/or linear displacements of the said support surface, and/or the said first auxiliary surface, and/or the said second auxiliary surface and/or the said third auxiliary surface is or are effected by electromagnetic actuators.

8. Apparatus as claimed in Claim 7, in which the said electromagnetic actuators are linear actuators and/or linear motors.

9. Apparatus as claimed in any preceding claim, in which the said support surface is mounted with respect to a fixed frame for rotary displacement about and linear translational displacement with respect to at least two orthogonal axes.

10. Apparatus as claimed in Claim 9, in which the said first surface is displaceable with respect to the said fixed frame with six degrees of freedom.

11. Apparatus as claimed in any preceding claim, in which the said support surface, and/or the said first auxiliary surface and/or the second auxiliary surface has or have means for varying its apparent hardness.

12. Apparatus as claimed in Claim 11, in which the said means for varying the apparent hardness of the said support and/or auxiliary surfaces is operative to vary the apparent hardness of a limited region of the overall area of the said support surface and/or auxiliary surface.

13. Apparatus as claimed in any preceding claim, in which the said support surface is an upper surface of a compressible element, there being an underlying incompressible element extending over less than the entire area of the said compressible element and relatively displaceable with respect thereto in association with movements of the said support surface at least about the said one axis whereby to vary the state of compression of the said compressible element in association with rotary and/or linear displacements thereof.

14. Apparatus according to Claim 13, in which the said substantially incompressible underlying element is one of two elements positioned in relation to a seat surface such as to underlie the ischial protuburances of a user seated on the surface.

15. Apparatus as claimed in any preceding claim, in which the said support surface is held in a determined position against displacement from an applied load such as the load of a seated user, by a compressible fluid in contact with a part of the underlying surface area of the support surface or an element supporting it.

16. Apparatus as claimed in Claim 15, in which the pressure of the fluid is varied

automatically and controlled by weight-sensing means or by electromagnetic power-consumption means.

17. Apparatus as claimed in any preceding claim in which displacement of the support surface by an applied load, such as the weight of a user, is supported by compliant material or a combination of different compliant materials.

18. Apparatus as claimed in Claim 17, in which the compliance of the or some of the said compliant materials is or are variable in dependence on the weight of a user.

19. Apparatus as claimed in any preceding claim in which the said support surface is the seat squab of a seat structure, the first auxiliary surface is a seat back, the second auxiliary surfaces are opposite sides of the seat squab, and the third auxiliary surface is a foot rest.

20. A method of simulating motion by causing displacements of a support surface in relation to a user supported thereby in the directional sense of the relative motion which would like place between the user and the support surface as a consequence of the simulated motion.

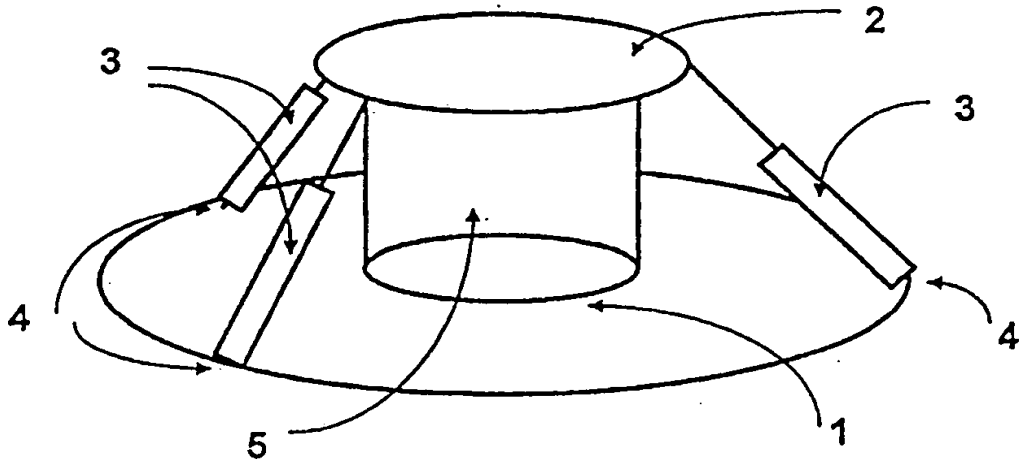


Fig 1

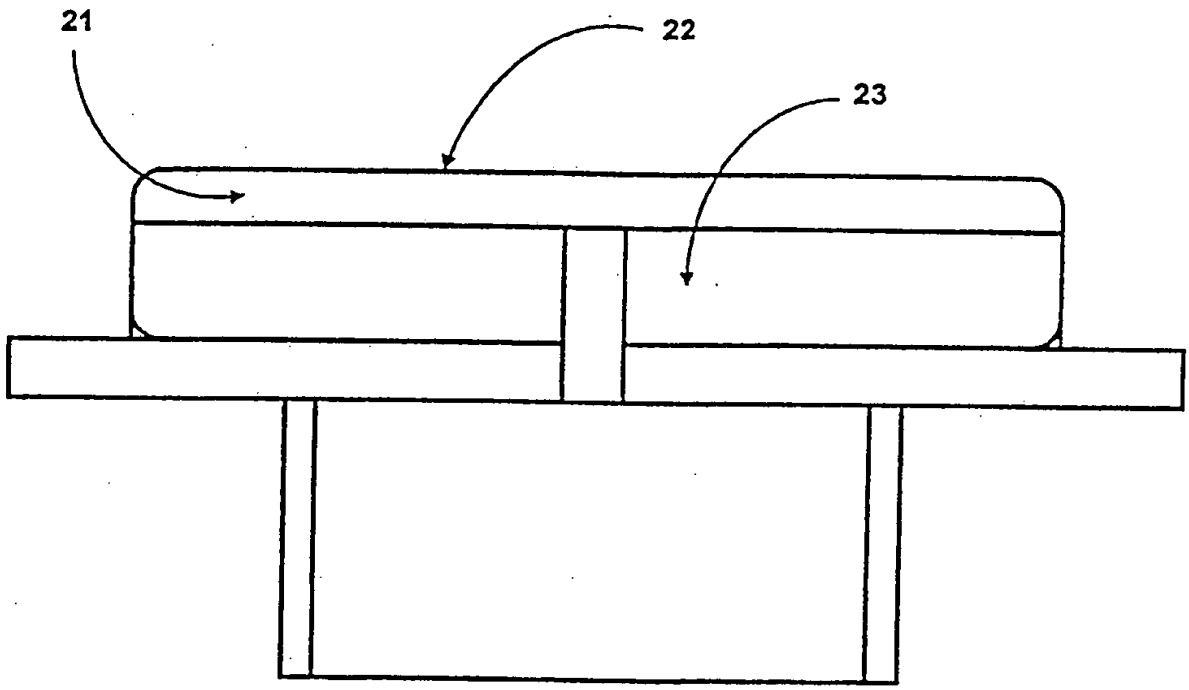


Fig 2

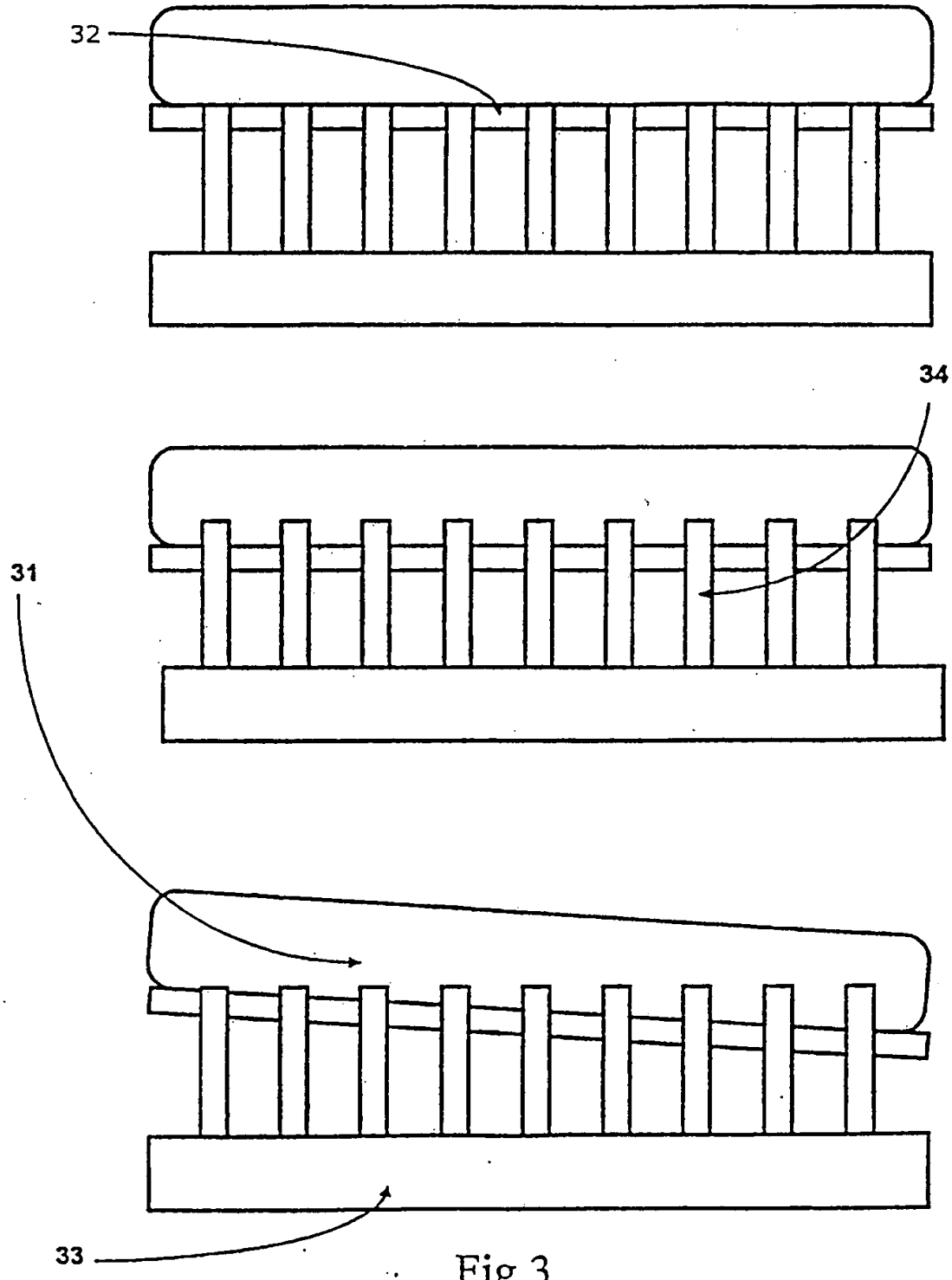


Fig 3

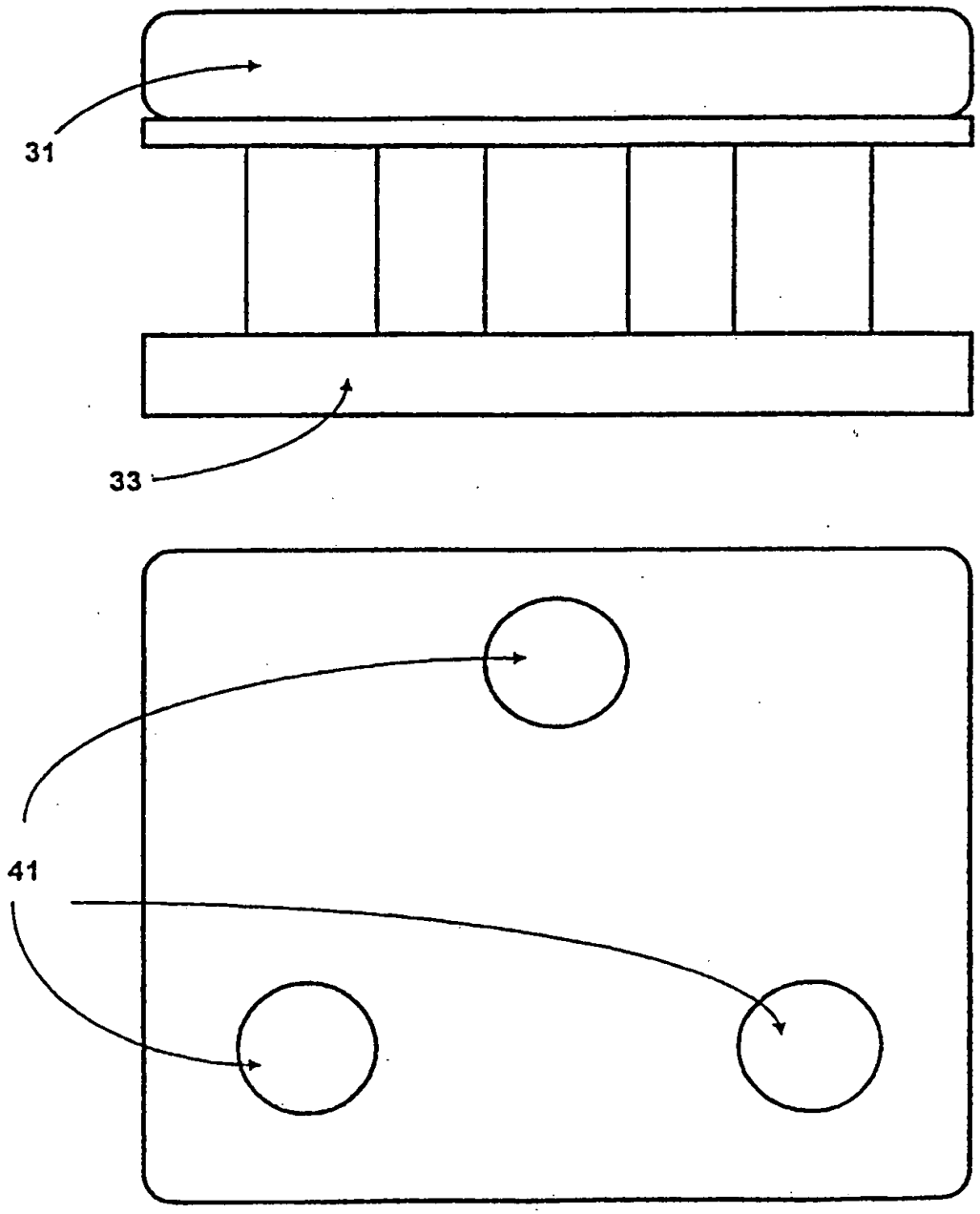


Fig 4

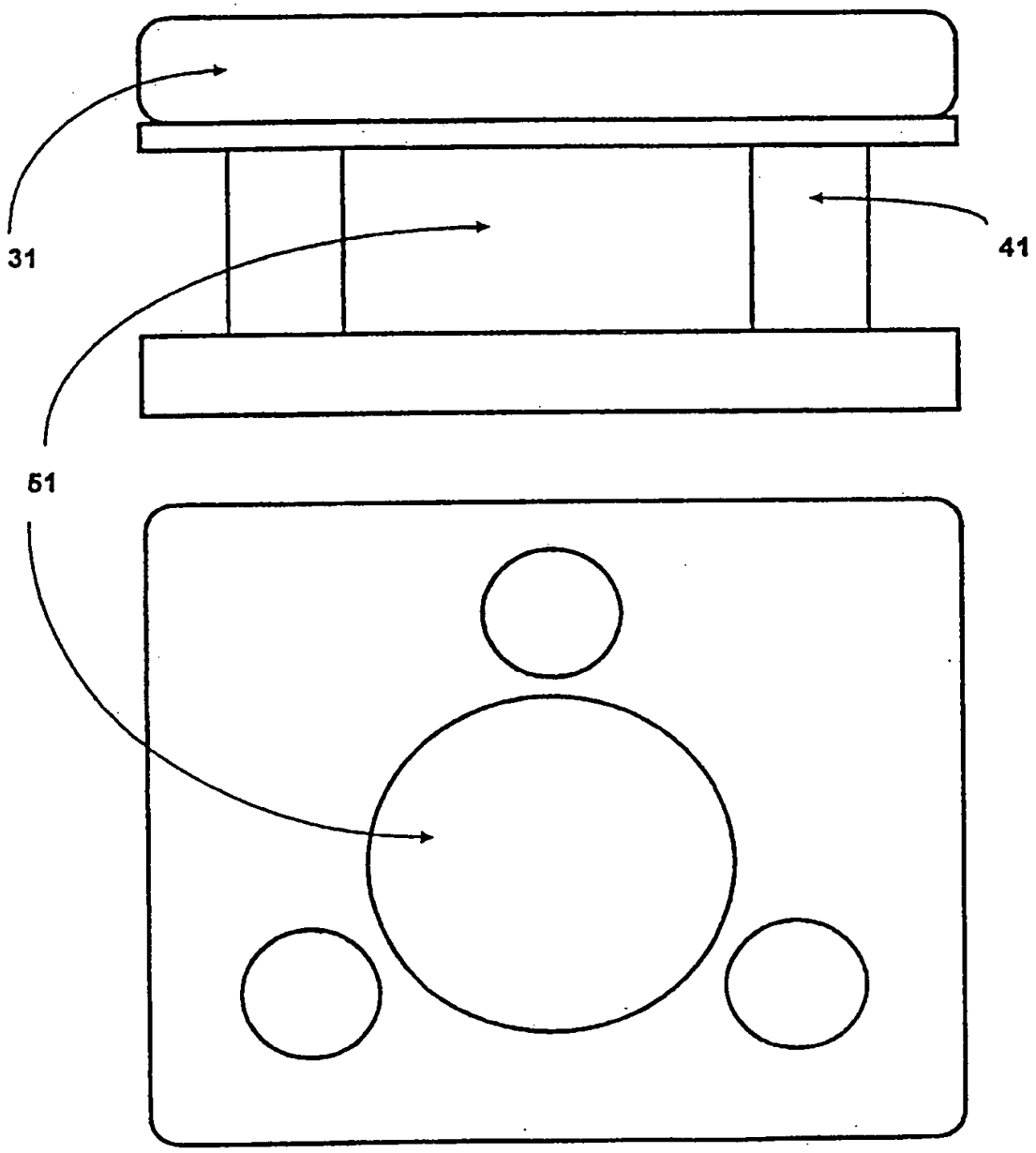


Fig 5

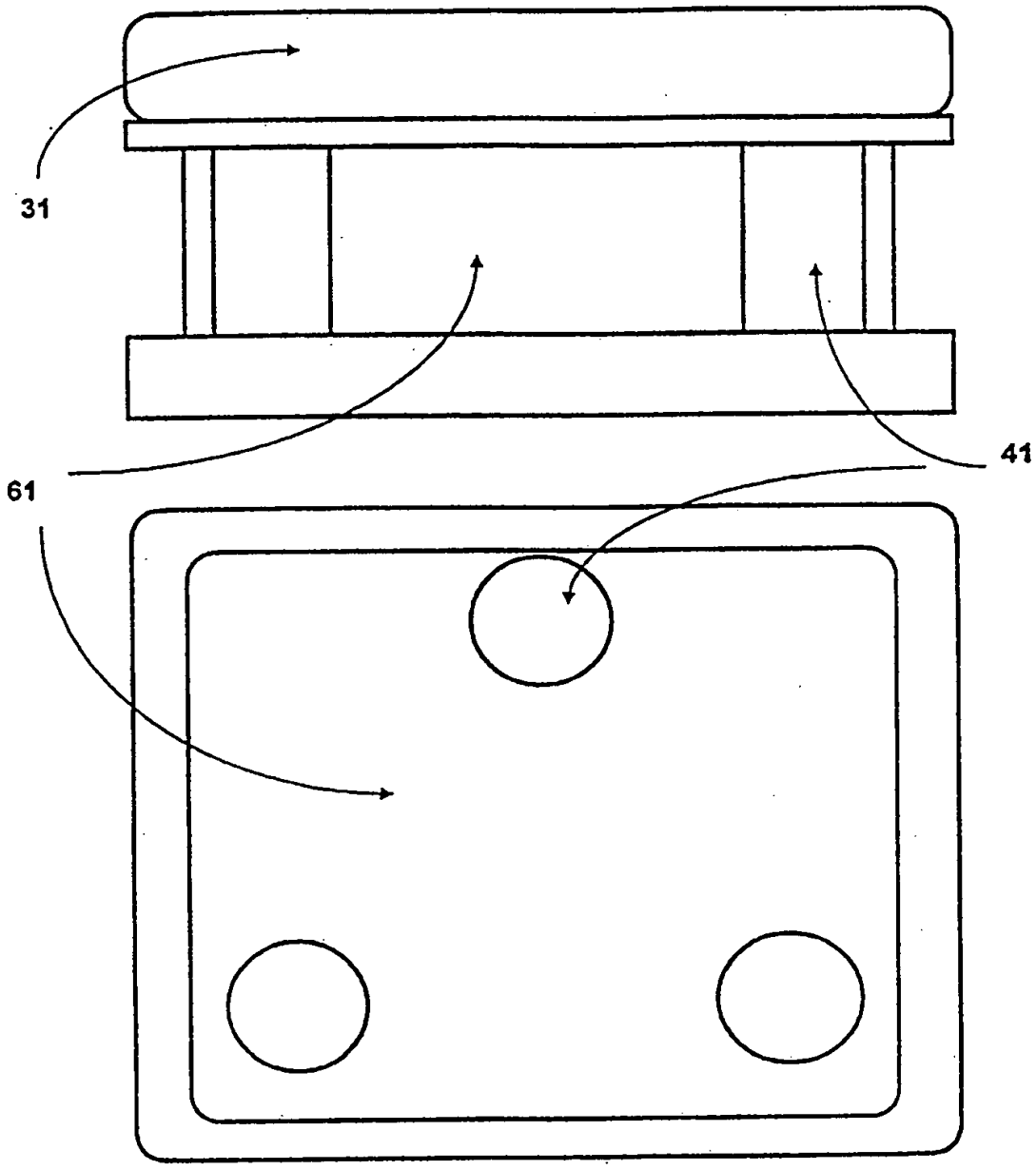


FIG 6

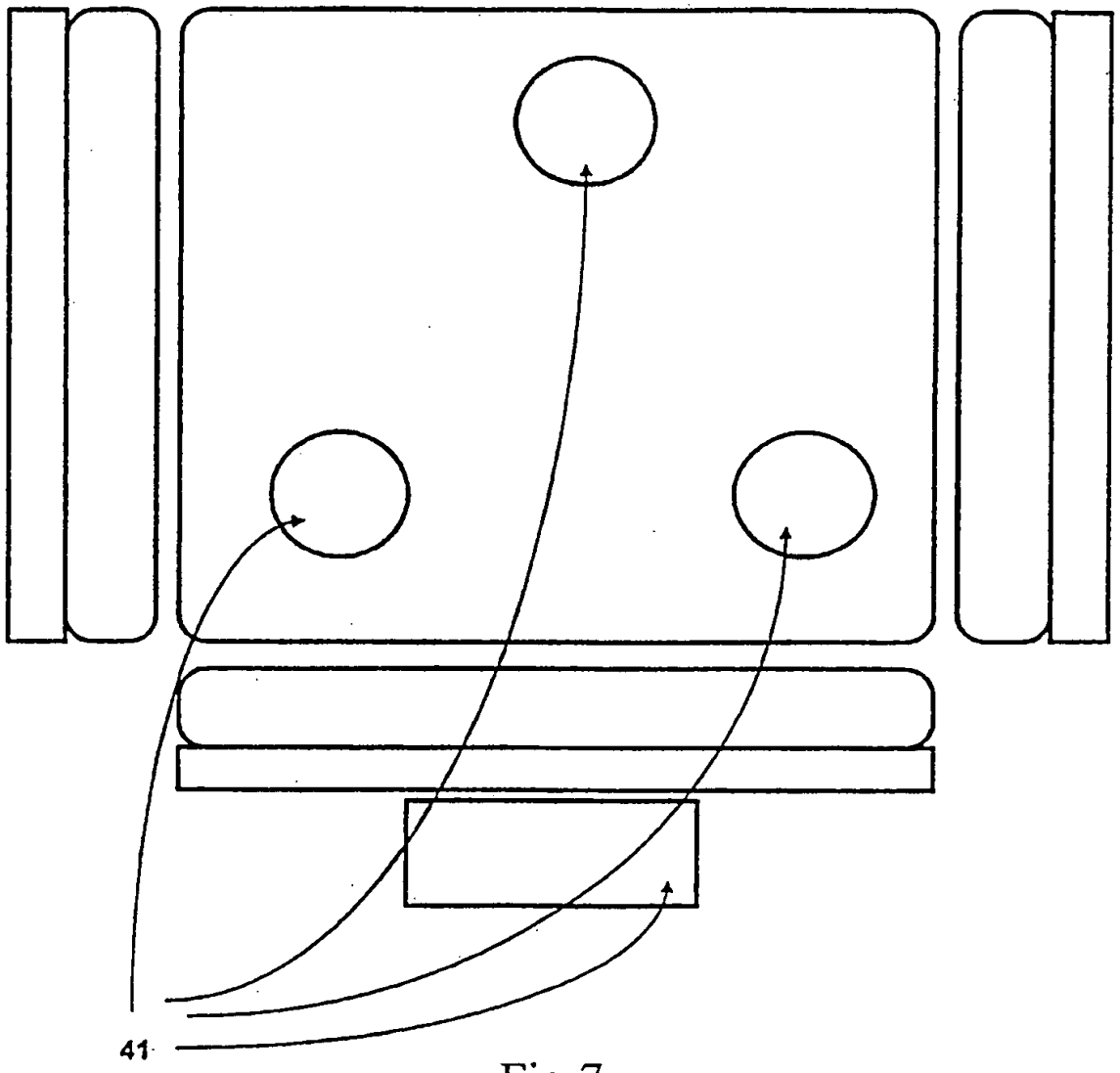
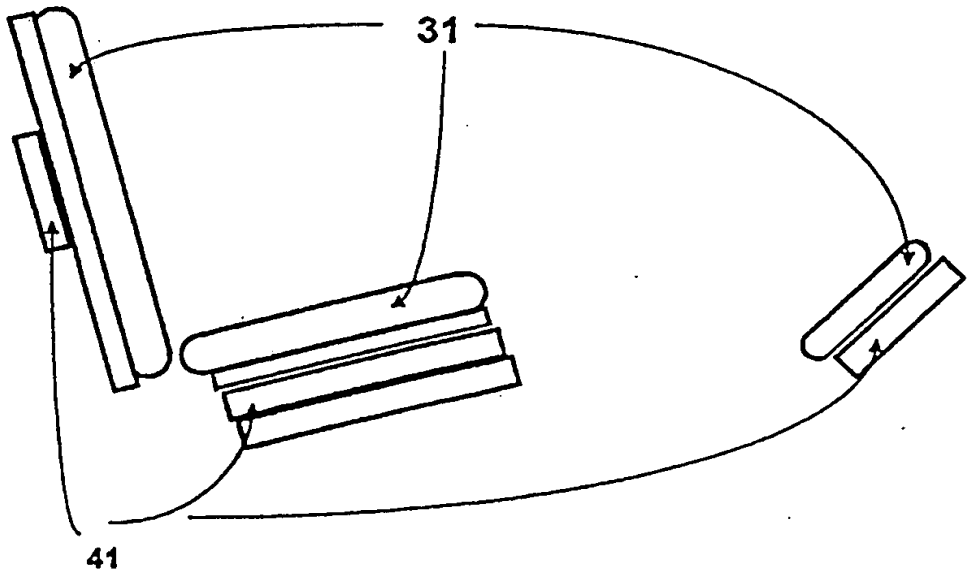


Fig 7

Fig 8



INTERNATIONAL SEARCH REPORT

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A. CLASSIFICATION OF SUBJECT MATTER
IPC 7 G09B9/10 G09B9/12 G09B9/02 A63G31/16

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC 7 G09B A63G

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
P,X	US 5 980 255 A (LE-HUU PASCAL ET AL) √ 9 November 1999 (1999-11-09) the whole document	1,3, 15-19
A	US 4 321 044 A (KRON GERALD J) √ 23 March 1982 (1982-03-23) the whole document	1-3, 11-13, 15-17
A	US 4 030 207 A (KRON GERALD J) 21 June 1977 (1977-06-21) column 3, line 61 -column 11, line 42; claims 1-29; figures 1-8E	1-5,11, 12,15-20
A	FR 2 696 859 A (SZAJNER BERNARD) 15 April 1994 (1994-04-15) the whole document	1,9

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[X] Further documents are listed in the continuation of box C.

[X] Patent family members are listed in annex.

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C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT

Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	US 5 605 462 A (DENNE PHILLIP R M) 25 February 1997 (1997-02-25) column 7, line 16 -column 7, line 56; claims 1-3; figure 5	1,7-9

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INTERNATIONAL SEARCH REPORT

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